

# APPENDIX R -- REVIEW OF METHODS THAT COULD POTENTIALLY BE USED TO DEVELOP MFL CRITERIA

## CONTENTS

Methods Considered for Use.....	R-1
Conceptual Basis for Minimum Flows .....	R-1
Recent Advances in Flow Analysis .....	R-2
Restoring Natural Flow Regimes .....	R-2
Richter “Range of Variability” Criteria.....	R-2
Synthesis and Application.....	R-3
Methods Considered for Use For the Loxahatchee River.....	R-3
Assessment of Methods Relative to the Loxahatchee River.....	R-4
Literature Cited .....	R-6

## METHODS CONSIDERED FOR USE

### Conceptual Basis for Minimum Flows

River management is a complex process that requires consideration of a number of variables. Minimum flows are an important component of riverine flow characteristics. However, providing a minimum flow represents only one aspect of management and/or restoration of river hydrology. Focusing on a single aspect of river hydrology (minimum flows) is an overly simplistic treatment of complex ecosystem interactions. Long-term hydrological data, especially measures of variability, have been under utilized in most management decisions aimed at river ecosystem protection or restoration (National Research Council 1992).

Because of the intrinsic ecological complexity of estuaries, scientists and managers have also objected to the idea that minimum flows can be set for estuaries. Complexity in itself is not a sufficient reason to question the concept of minimum flows for estuaries. In fact, it simply supports the fact that complex biological systems, such as those in estuaries, require more study. Due to the lack of understanding and a shortage of previous attempts to establish minimum flows, estuarine scientists and managers do not have even simplistic minimum flow examples to study or criticize. Rather than waiting until all information is available before making a management decision, the best approach is adaptive: set inflows based on assumptions derived from conceptual and mathematical modeling using best available information, monitor the results for success or failure, continue research, and reevaluate flow targets.

## Recent Advances in Flow Analysis

### Restoring Natural Flow Regimes

Because modifications of hydrologic regimes in rivers are known to directly and indirectly alter the composition, structure, or function of riverine aquatic and wetland ecosystems, most river scientists tend to agree that it is better to approximate natural flow regimes and maintain entire ensembles of species, than to optimize water regimes for one or a few species. In reality, however, the great majority of in stream determinations have been based on one or a few species' requirements. It is now understood that native aquatic biodiversity depends on maintaining or creating some approximation of natural flow variability, and that native species and communities will perish if the environment is pushed outside the range of natural variability. Where rivers are concerned, a natural flow paradigm is gaining acceptance. It states “the full range of natural intra- and interannual variation of hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems” (Richter et al. 1997). A corollary idea is that ensembles of species and ensembles of habitats should be used to gage the effect of hydrological alteration. Sentiment for a similar paradigm for estuaries is growing. In river-dominated estuaries, it seems reasonable to evaluate both flows and salinities with respect to their multiple forms of variation.

### Richter “Range of Variability” Criteria

A new and robust method was developed for determining hydrologic alterations in rivers (Richter et al. 1996). The “range of variability approach” is based on the calculation of means and coefficients of variability of 32 hydrologic variables grouped into five sets:

- Magnitude of monthly water conditions
- Magnitude and duration of annual extreme conditions
- Timing of annual extreme water conditions
- Frequency and duration of high and low pulses
- Rate and frequency of water condition changes

Comparisons are made between “before” and “after” modifications. In the absence of “before” data, models can be used to estimate water conditions. Some alterations affect only a few indicators, whereas others affect many. Patterns of alteration help managers determine the aspects of flow to modify.

This technique employs more variables and offers more promise in protecting ecosystem integrity. It is gaining in popularity and has been used extensively by the Northwest Florida Water Management District in its role in the Apalachicola-Chatahoochee-Flint Tri-State Compact (USACE 1998). In cases where restoration is sought for a system with no “natural” flow data, it is necessary to employ hydrologic

simulation models to estimate historical conditions. While such models may provide good estimates of impact magnitude, they do not illuminate their causes. Nevertheless, the method captures a number of features, especially rates of change, that are not commonly used in estuarine science and management, but may have important effects on estuarine ecosystems.

The “range of variability approach” can be applied, even when flow data are scant, to set initial river management targets for rivers in which the flow regime has been greatly altered by human developments such as dams and large diversions. If adequate stream flow records exist for at least 20 years of natural conditions, the method can be used directly. In the absence of all 20 years of data, missing data can be estimated. In the absence of any data, models may be employed or normalized estimates can be generated from nearby, similar streams. Some hydrologic variables cannot be generated by these latter methods, affecting the power of the technique.

The criteria for streams pose great difficulty for estuarine managers where tributary data are sparse; where tributaries have been extensively altered for long periods of time; or where regulated flows are only part of an estuary's total freshwater budget.

## Synthesis and Application

### Methods Considered for Use For the Loxahatchee River

Several general methods were identified that could be used to establish minimum flows for the Loxhatchee River and Estuary. Components of five possible approaches are integrated in this study. These methods are described generally below, followed by assessment of their applicability.

**1. In Stream Flow Methods.** Historical flow, hydraulic, or habitat methods can be used to determine acceptable flows of individual tributaries to rivers (Stalnacker et al. 1995). This approach presumes that a river or estuary's needs for fresh water can be met by providing sufficient flow from tributary surface waters; that the majority of inflow occurs via streams, rivers, canals or other gaged surface waters; and that data are available or can be obtained.

**2. Hydrological Variability Techniques.** Following Richter et al. (1996) this approach extends the in stream techniques through a fuller analysis of flow characteristics. An untested but feasible application of the method would be its use with salinity data rather than flow data. Data requirements are large, but most types of salinity data could be generated through the use of models. Results of natural or historical conditions would be compared to existing or predicted conditions of salinity.

**3. Habitat Approaches.** Browder and Moore (1981) proposed the concept of analyzing the overlap of dynamic and stationary habitat elements for particular species. This approach could be developed more fully. If submerged aquatic vegetation was targeted, for example, the method would query the probability that appropriate depths,

sediment types, salinities, and conditions of water clarity coincided under differing flow regimes.

**4. Indicator Species.** This approach relates a change in abundance, distribution, or condition of particular species to a flow or salinity. Criteria for selection may include a species' commercial, recreational, or aesthetic value; ecological importance; status as a species at risk (threatened, endangered, etc.), or endemism. Statistical methods attempt to match abundance values to appropriately time lagged inflow or salinity conditions.

**5. Valued Ecosystems Component Approaches.** An extension of the indicator species approach, valued ecosystem component (VEC) analysis also uses statistical methods, but accounts for more known or suspected intermediate variables. Recommended by the United States Environmental Protection Agency (1987) for national estuary programs to characterize constraints to living resources, VEC analysis plays an important part in a general model for the design of eutrophication monitoring programs in South Florida estuaries. VEC is a goal driven approach that has the ability to focus research and provide managers with short-term alternatives in data poor estuaries.

## **Assessment of Methods Relative to the Loxahatchee River**

### **Hydrologic Methods**

A major limitation is the lack of historical flow and salinity data for the Loxahatchee River and Estuary from prior to construction of the inlet, drainage by major canals, and dredging of the waterways. Some aspects of the historical (natural) flow regime can be inferred, however, from anecdotal information, historical records and analysis of remnant vegetation such as tree rings (Duever and McCollum, 1982), dead trees and stumps, but there are virtually no hydrologic, water quality or biological data from this watershed prior to about 1970.

A possible approach to overcome this lack of information is to develop a hydrological model to represent historical water levels and flow patterns. The SFWMD has a regional model that is used to simulate conditions that existed in South Florida during the 19th century. This so-called "Natural Systems Model" is used to predict water levels and distribution over the entire South Florida region, including the Loxahatchee River watershed. Unfortunately, because the model was designed for a very large area, it provides low resolution at any particular location, and is not sufficient to provide accurate estimates of water levels or flows in the Loxahatchee watershed. Additional effort is needed in the future to extend this model, at a higher resolution, to provide more detailed analyses for northern Palm Beach and southern Martin Counties.

In lieu of the NSM, an attempt was made to predict historical (pre-development) flows from the Loxahatchee River watershed based on historical land use/land cover data, climatological data, and water level information from throughout the region and general topographic features of the basin. This approach provided a general picture of flow patterns and estimated annual average volumes of runoff, but was not considered to

adequate for prediction of dry season, low-flow conditions. Additional efforts will be made to refine this approach during the coming year. In addition to the above modeling approaches, the following methods were used to analyze actual data from the watershed:

**1. Instream Flows.** This included an assessment of existing inflows to the river from different surface water sources and estimates of groundwater inflow along different stretches of the river. The hydrodynamic model was also used, in combination with historical USGS flow records, to simulate a 30-year salinity record for the period from 1971-2000, at selected sites along the Northwest Fork. Additional efforts are underway to identify methods that can be used to enhance flows to the river in the future. Most of the emphasis so far has been placed on examination of resources in northern Palm Beach County. Plans are underway to provide additional storage and improve water conveyance capacity to provide additional flow to the River from Loxahatchee Slough and the regional water management system. Opportunities in other basins (e.g. Kitching Creek, Pal/Mar Cypress Creek and Hobe Groves) are being investigated now for inclusion in future updates of this document.

**2. Hydrologic Variability.** The range of inflows to the river was examined with emphasis on long-term average flows, dry season flow conditions and the magnitude, frequency and duration of low flow events. This approach needs to be expanded in the future to consider wet season flow conditions as well as maximum flow events with recognition that the full range of natural flow conditions needs to be addressed in this process. Full use of this approach has been delayed until modeling tools have been developed that provide a better picture of natural historical flow conditions that occurred in the River.

### **Biological Methods**

Results of field vegetation studies and peer review of an earlier draft of this document indicated that the decision to use a single species, cypress, did not provide an adequate basis to protect critical resources in the Loxahatchee River, especially since cypress trees were not the most sensitive or responsive vegetation species to river flow and/or salinity changes. The panel suggested that a broader, community-based approach would be more appropriate. In response to this recommendation and the results of recent field studies, SFWMD staff considered the use of habitat, indicator species, and Valued Ecosystem Component approaches as described below.

**3. Habitat Approaches.** The evaluation of biological response to changes in flow was expanded to consider the freshwater floodplain swamp community as an important river habitat. In a fully functional floodplain swamp ecosystem, freshwater trees, in conjunction with cypress, comprise a multi-layer canopy that provides the aesthetic basis for the “wild and scenic” river as well as a range of living conditions for native birds, mammals, reptiles, amphibians and invertebrates. Factors that impact the distribution and health of this community were analyzed including river flow, salinity and soils. In addition, 30 or more associated herbaceous floodplain plant species that

primarily comprise the understory of this community were also identified as a critical component of this habitat.

**4. Indicator Species.** Six species of hardwood trees were identified as indicator species for the freshwater swamp community. Distribution of these species along the river was documented and related to river flow, surface water salinity and soil salinity conditions.

**5. Valued Ecosystem Component (VEC).** The indicator species approach was expanded to include the VEC concept. Management goals were established based on protection of the valued ecosystem component, which in this case represents those freshwater vegetation species that are most sensitive to the environmental factor of interest (salinity). It is assumed that providing a minimum freshwater flow to the river that will protect this group of species against saltwater intrusion will also protect the entire community. Results of a river vegetation survey identified six “key” woody vegetation species characteristic of the floodplain swamp that appear to be more sensitive to the effects of long-term salinity conditions within the river as compared to bald cypress, cabbage palms or red mangroves. These six species are also important structural components of the forest canopy, and play a number of other functional roles in the forest ecology. Impacts to the VEC beyond a critical level is considered to constitute significant harm to the river floodplain swamp community.

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